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DEVELOPMENT AT THE NAVY. (U) NAVY PERSONNEL RESEARCH
AND DEVELOPMENT CENTER SAN DIEGO CA R PENN ET AL.
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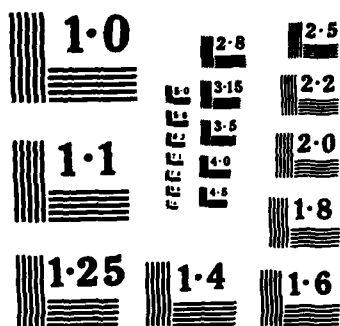
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**INDEPENDENT RESEARCH AND INDEPENDENT
EXPLORATORY DEVELOPMENT AT THE NAVY
PERSONNEL RESEARCH AND DEVELOPMENT
CENTER -- FY84**

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San Diego, California 92152**



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May 1985

**INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT
AT THE NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER--FY84**

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) This report provides synopses of FY84 Independent Research (IR) and Independent Exploratory Development (IED) projects, the IR/IED funding profile, and a list of publications and presentations on IR/IED projects. In the IR section, new research methods for measuring task difficulty and worker ability, for collecting problem-solving strategies, and for collecting simultaneous data on cognition and emotion during task performance are described. Personnel testing is addressed through an evaluation of new formulas for range restriction and a polychotymous model for scoring multiple choice items that uses information from wrong answers. Potential training innovations are described for concepts in basic electronics, memory for procedural tasks, and career-role learning by officers. Computerized decision aids for surveillance tasks and opportunities for exploiting the huge individual differences in worker productivity were also studied. In the IED section, manpower related projects include a model for the man-job match by multiple policy criteria, the integration of current definitions of "manpower supply," and a market segmentation analysis of Navy retention incentives. Computerized aids for plain English in military documents and for tactical action officer training were also developed in FY84 IED.					
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FOREWORD

Independent Research (IR) and Independent Exploratory Development (IED) funds are provided to the Technical Directors of Navy Laboratories to give them wide latitude to perform innovative, promising work without the procedure of formal and prior approval which might delay normal funding authorization.

The IR program at the Navy Personnel Research and Development Center has been active since the Center was formed in 1973. It is funded under PE61152N. The IED program was initiated in FY76 and is funded under PE62766N. The Center received the Director of Navy Laboratories award for science excellence based on the IR/IED corporate review conducted in 1982.

This report is submitted to fulfill the requirement for an annual IR/IED report (NAVMATINST 3920.3C). It provided summaries of selected FY84 projects, the program funding profile, and a list of publications and presentations resulting from IR/IED efforts.

J. E. KOHLER
Commander, U.S. Navy
Commanding Officer

J. W. TWEEDDALE
Technical Director

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INDEPENDENT RESEARCH (IR) PROGRAM

The Navy Personnel Research and Development Center (NAVPERSRANDCEN) has been conducting Independent Research (IR) since its establishment in 1973. The program provides an opportunity for Center personnel to conduct basic research in innovative domains that may have potential long term benefits for the Navy. Resources provided for the program have been used to develop a variety of research methods, models, and techniques within the broad areas of training, manpower utilization, organizational productivity, and human factors in the design of Navy weapon systems and platforms.

IR work units for FY84 and FY85 are listed in Table 1. The publications and presentations produced by this work are listed in Appendix A. Work conducted within selected units during FY84 is described in the remainder of this section.

Table 1
Independent Research Work Units for FY84 and FY85

61152N	Project Title	Principal Investigator	Funding in \$K	
			FY84	FY85
ZR000-01-042-04				
.005	Models and Measures of Human Performance ^a	Dr. R. Sorenson AV: 933-6617 Code 71	10	0
.021	Treatment of Restriction of Range in Navy Personnel Research ^a	Dr. E. Alf AV: 933-2408 Code 62	20	0
.024 042.06	Models for Calibrating Multiple Choice Items	J. Sympson AV: 933-6153 Code 62	30	69
.041	Enhancing Understanding of Electric Circuits	Dr. W. Montague AV: 933-7100 Code 05	50	30
.017	Generalizable Cognitive Strategies	Dr. M. Baker AV: 933-6955 Code 51	40	0
.025	Cognitive and Emotional Processing	Dr. B. McDonald AV: 933-6434 Code 51	51	15
.027	Cognitive Factors in Learning and Retention	Dr. J. Ellis AV: 933-6434 Code 51	37	10
.028 042.08	Cognitive Storage Mechanisms ^b	Dr. M. Baker AV: 933-6955 Code 51	0	14
.023	Acquiring Skill From Work Experience ^a	Dr. R. Morrison AV: 933-6911 Code 62	27	0
.030 042.09	Positively Accelerating Sharing Rates	Dr. D. Nebeker AV: 933-6935 Code 72	0	25
.020	Analysis of Cognition in Natural Settings	Dr. E. Hutchins AV: 933-6242 Code 501	12	80
.022	Models of Human Performance With Application to Decision Aiding	Dr. F. Greitzer AV: 933-2081 Code 71	45	0
.026	Effects of Exercise and Nutrition on Vigilance ^b	Dr. J. McGrath AV: 933-7424 Code 71	8	0
	Military Leadership	Dr. L. Atwater AV: 933-6935 Code 72	0	34
	Relationships Between Management Practice and Organizational Performance	Dr. K. Crawford AV: 933-6935 Code 72	0	35
	Expert Systems for Fault Diagnosis	Dr. Don Malkoff AV: 933-6617 Code 71	0	38
			330	350

^aCompleted at the end of FY84.

^bTerminated in FY85 due to reprioritization of Center research efforts.

A MODEL FOR MEASURING TASK DIFFICULTY AND WORKER ABILITY¹

Richard C. Sorenson

Background

In an evaluation of technological, organizational, or incentive changes, it is necessary to measure the performance of individuals on specific job tasks. This is difficult when individuals perform several different job tasks during any given work period. Thus, models are required that allow us to solve for parameters associated with task difficulty as well as worker ability from the number of times tasks are performed and the time spent performing them.

Development of an Initial Model

Suppose we have a work situation in which we have I individuals performing J different job tasks and that we have measurements over K weeks. We will let

X_{ijk} = the number of times the j^{th} job task was performed by individual i during week k.

t_{ik} = the time spent by individual i performing job tasks during week k.

A_{ik} = the inverse of ability or proficiency associated with individual i during week k. A_{ik} is the length of time individual i took to perform a standard set of tasks relative to the average individual during week k.

B_{jk} = the difficulty associated with job task j during week k. B_{jk} is the average length of time it takes to perform the j^{th} job task.

We have measures for X and t, and desire to solve for A and B using the relationship:

$$\sum_{j=1}^J A_{ik} X_{ijk} B_{jk} = t_{ik} \quad (1)$$

We will let

${}_kX$ = the $I \times J$ matrix of the X_{ijk} s for the k^{th} period.

${}_kD_A$ = the $I \times I$ diagonal matrix of the A_{ik} s for the k^{th} period.

${}_kB$ = the J^{th} order vector of the B_{jk} s for the k^{th} period.

${}_kT$ = the I^{th} order vector of the t_{ik} s for the k^{th} period.

¹This article presents one of several models dealing with measuring task difficulty and person ability developed under work unit ZR000-01-042.005: Models and Measures of Human Performance.

From the above definitions and (1), we specify the model

$${}_k D_A {}_k X {}_k B - {}_k T = {}_k e \quad (2)$$

by which we will determine the individual parameters, A, and the task parameters, B, so that the sum of squares of the e values in (2) is a minimum subject to certain constraints on A and B. We shall constrain A and B to be equal for different periods:

$${}_k D_A = D_A \text{ for all } k = 1 \dots K \quad (3)$$

$${}_k B = B \text{ for all } k = 1 \dots K \quad (4)$$

and the sum of the person parameters is I, the number of individuals:

$$1' D_A = A' \quad (5)$$

$$A' 1 = I \quad (6)$$

We will solve for the unknown A and the unknown B by an iterative approach since equation (2) involves their product. We let

$${}_k D_A {}_k X = {}_k Z \quad (7)$$

and from (2) and (7)

$${}_k Z {}_k B - {}_k T = {}_k e \quad (8)$$

The least squares solution for ${}_k B$ in (8) can be shown to be

$${}_k B = ({}_k Z' {}_k Z)^{-1} ({}_k Z' {}_k T) \quad (9)$$

Because of the constraint of (4), we set the values of B equal to the mean of the values ${}_k B$ as indicated in the scalar equation (10):

$$B_j = \frac{1}{K} \sum_{k=1}^K B_{jk} \quad (10)$$

and refer to the vector of B_j values as B. If we denote ${}_k \tilde{T}$ as an estimate of ${}_k T$, then from (8) and (10) we have

$${}_k \tilde{T} = {}_k Z B \quad (11)$$

From (2), (7), and (11)

$$D_A \hat{{}_k \tilde{T}} - {}_k T = {}_k e \quad (12)$$

where D_A is a diagonal matrix of multipliers to update D_A from one iteration to another to be solved for by minimizing $e'e$. Recalling the constraints of (3) we write (13) in scalar notation.

$$\tilde{T}_{ik} \hat{A}_i - T_{ik} = e_{ik} \quad (13)$$

The solution for (13) to minimize $\sum_{k=1}^K e_{ik}^2$ is

$$\hat{A}_i = \frac{\sum_{k=1}^K \tilde{T}_{ik} T_{ik}}{\sum_{k=1}^K \tilde{T}_{ik}^2} \quad (14)$$

Thus, we may now update $D_{\hat{A}}$ and impose the constraint of (6) with the replacement equations

$$A_i = \hat{A}_i A_i \quad (15)$$

$$A_i = \left(\begin{array}{c|c} I & -I \\ \hline \sum_{i=1}^I A_i & A_i \end{array} \right) \quad (16)$$

Computer Algorithm

We are now ready to specify our iterative solution:

1. Choose an initial estimate for D_A . (The identity matrix would be appropriate.)
2. Calculate B by equations (7), (9), and (10).
3. Calculate A by equations (11), (14), (15), and (16).
4. Test to see if any B or any A has been modified more than a tolerance limit, ϵ , and if so return to step 2 and if not, calculation is completed.

Application

The initial model was evaluated by applying it to data gathered in a government agency that dealt with expenditures related to government contracts. In the particular unit studied, the staff members processed four different kinds of payments. A total of 21 employees were involved over a period of 18 weeks. Thus, $I=21$, $J=4$, and $K=18$. The iterative solutions for the vector of task difficulty parameters, B, is given in Table 1. Table 2 provides the solutions for A, the ability parameter. Iterations were continued until the largest change in an A or B element was less than .05. The estimates of the ability parameters converge rapidly. It appears that some individuals perform tasks in as little as 56 percent of the average time, while others take 67 percent more time than average.

Table 1
Iterative Solution for Difficulty Parameters for Four Tasks

Task	Iteration								
	1	2	3	4	5	6	7	8	9
1	91.65	65.09	56.82	53.99	52.91	52.49	52.33	52.26	52.24
2	14.89	23.69	26.69	27.85	28.31	28.49	28.56	28.58	28.59
3	20.61	26.21	27.23	27.63	27.79	27.85	27.88	27.89	27.89
4	24.26	27.20	26.48	26.14	26.00	25.95	25.93	25.92	25.92

Table 2
Iterative Solution for Ability Parameters

Individual	Iteration								
	1	2	3	4	5	6	7	8	9
1	1.45	1.51	1.53	1.54	1.54	1.54	1.54	1.54	1.54
2	1.06	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01
3	1.17	1.23	1.25	1.25	1.26	1.26	1.26	1.26	1.26
4	1.60	1.64	1.66	1.67	1.67	1.67	1.67	1.67	1.67
5	.61	.60	.59	.59	.59	.59	.59	.59	.59
6	1.08	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04
7	1.09	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
8	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
9	1.07	1.09	1.10	1.10	1.10	1.10	1.10	1.10	1.10
10	.88	.86	.85	.85	.85	.85	.85	.85	.85
11	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01
12	.97	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01
13	1.09	1.07	1.06	1.06	1.06	1.06	1.06	1.06	1.06
14	.90	.93	.94	.94	.94	.94	.94	.94	.94
15	.79	.81	.82	.82	.82	.82	.82	.82	.82
16	1.00	.93	.91	.90	.89	.89	.89	.89	.89
17	.61	.62	.63	.63	.63	.63	.63	.63	.63
18	.60	.61	.61	.61	.61	.61	.61	.61	.61
19	1.22	1.19	1.19	1.18	1.18	1.18	1.18	1.18	1.18
20	.58	.56	.56	.56	.56	.56	.56	.56	.56
21	1.14	1.10	1.08	1.08	1.08	1.07	1.07	1.07	1.07

INDIVIDUAL DIFFERENCES: AN UNDERDEVELOPED OPPORTUNITY FOR MILITARY PSYCHOLOGY¹

Bernard Rimland

Gerald E. Larson

Background

Students of warfare have stated with striking regularity that military victories have depended more often upon the quality of the soldiers than upon their numbers or the superiority of their weapons. As stated by Brackney (1959), man's success has "depended more on how he has used his weapons than upon any superiority of weapons design and performance."

History shows many examples where the tide of battle, and ultimately the tide of war, has hinged on the spectacularly effective performance of just a few individuals. The story of Audie Murphy is an interesting case in point. Murphy, who was only 5'5" tall and weighed just 110 pounds, was rejected by both the Navy and Air Force before being accepted for duty by the Army. Recounting even a portion of his extraordinary performances would take more space than this article. He became the most decorated soldier of World War II, winning 33 military awards, citations, and decorations, including every possible American medal for valor as well as three French medals and one Belgian medal (Simpson, 1975). Similarly, in World War I, Baron Von Richthofen alone was responsible for downing 80 enemy aircraft (Carisella & Ryan, 1969), while an American, Samuel Woodfill, single-handedly overcame three German machine gun nests in one afternoon, dispatching 21 soldiers (Blumenson & Stokebury, 1975).

These are not isolated instances. In summarizing the findings of Brigadier General S. L. A. Marshall, Toomepuu (1980) noted:

Marshall has published important findings on combat performance of soldiers in World War II, in Korea, Viet Nam, and the Arab/Israeli wars. While gathering historical data from front line infantry units during World War II, Marshall made the startling discovery that only about 15 percent of the soldiers in battle actually fired their weapons, and that the fighters were observedly different from the other soldiers. In a bitterly fought battle for Omaha Beach, he found that on a two division front only six rifle companies could be considered effective as units, and only 47 men, at widely scattered intervals along the beach, saved the day from disaster. Marshall concluded that the outcomes of battles are decided by relatively few effective participants, a conclusion supported by other astute observers of the performance of soldiers in battle. (p. 5)

In contrast, a single ineffective performer in a key position can cripple a mission. Incompetence on the part of the B-29 aircraft commander, radar observer, or bombardier often led to failure of the entire mission (Bass, 1982). The outcome of the recent

¹This article summarizes a more lengthy paper submitted for journal publication prepared under work unit ZR000-01-042.005: Models and Measures of Human Performance.

Falkland Islands conflict might have been different if the final Argentine Exocet missile had not been mistakenly wasted on a cargo ship. Dixon (1976), in On the Psychology of Military Incompetence, attributes many fiascos to defects in various leaders. But whether one wishes to focus on human ability, personality, leadership, courage, or physical strength and stamina, it is clear that individual differences play an enormously important role in the outcome of endeavors. The purpose of this paper is to remind our readers of the extent and pervasiveness of individual differences, and to offer suggestions for research and applications.

The Magnitude of Performance Differences

The striking range of differences in human performance is apparent in every dimension imaginable (e.g., intelligence, musical talent, motivation, experience, athletic ability). Rather than the 10, 20, or even 30 percent difference that most people believe characterizes the span of performance, the actual range, even in small groups, rarely falls below 200 percent, and differences in the thousands of percents are not uncommon. Let us consider human performance differences in a few fields.

Academic/Intellectual Abilities

Striking differences between individuals have been found in studies of academic performance. In terms of test items correct, differences of several hundred percent (e.g., scores ranges of 30 to 90+) are commonly found in classrooms of rather homogeneous college students. In terms of scholastic achievement, some high school seniors, about 10 percent, surpass 50 percent of college seniors; in terms of reading ability, 10 percent of students in grade five read better than 50 percent of students in grade eight (both cited in Willerman, 1979).

IQ scores usually range between 80 and 150 in a large high school, but they grossly understate the actual range of difference in intelligence. In terms of number of test items correct (e.g., vocabulary, reasoning, general information, etc.), the individual with an IQ of 150 outscores the individual with an IQ of 80 by a ratio of 50:1. The mere 2:1 ratio in ability implied by the IQ scores is misleading. Consider, for example, the mental ability of mathematician George Willis (Wechsler, (1952). On one occasion Willis amused himself by mentally extracting the square root of a number containing 53 digits. A month later he was able to reproduce both the number and the root.

Industrial Productivity

Individual differences in productivity are usually vastly underestimated. When an industrial supervisor is asked to estimate the difference between the most and least productive employee, he or she will typically guess 20 to 30 percent. However, when actual production figures are available, it turns out that the average range of differences, even for simple tasks, has been about 200 percent.

If the job is simple, such as keypunching, typing, or operating a sewing machine, productivity differences in the range of 200 to 300 percent are common (Wechsler, 1952). In a recent review of the literature on individual differences in productivity, Schmidt and Hunter (1983) reported production data for 40 groups of workers studied from 1928 to 1978. The data were primarily from manual workers--machine operators, card punchers, typists, assemblers, etc. The productivity ratios, derived by comparing the most and least productive five percent of workers, ranged between 1.41 and 17.35! (The next lowest ratio below 17.35 was 3.46, still an immense difference between 5th and 95th percentile performers.) The average productivity ratio for simple tasks was about 2.00.

They requested that these tests be used to assist in evaluation of the new materials. Four groups of students (N = 22-30 each) who used either the revised materials or the standard materials were given either the CAUSE or the CHANGE tests during July-September 1984. One major change to the materials was the use of test items similar to those in the CHANGE test in the course pretests.

Results

The data are extensive and can receive only cursory review here. Of the first group of 46 students who had completed the 14 BE/E core modules successfully, only 4 made no errors on the CHANGE tests. It is important to recognize that these students had successfully passed the course and, in a sense, had been certified as sufficiently trained to go on to the next course. Subsequent administration of the tests revealed about the same high proportion of errors. Most students made multiple errors. Analysis revealed that there was consistency in the errors made--most errors were concerned with misunderstandings about voltage drop and current. This finding is in agreement with Riley's (1984) results. Preliminary analysis of the errors diagnosed by the CHANGE test indicates that consistent errors could be summarized by a few "buggy" (faulty) rules. The intention for use of the results is that an analysis of the student buggy rules which cause the errors will serve as the basis for changes in instructional materials to be tested during FY85.

The comparison of the groups receiving the revised or standard modules revealed no overall differences in the number or types of errors in the CHANGE or CAUSE tests. Again, errors revealed confusion between voltage drop and current. A more detailed analysis of these data is underway to examine any effects on test items most relevant to changes in the instructional content.

Conclusions

The ongoing research and analysis allows no definitive conclusions at present. However, certain general conclusions seem reasonable. The similarity of student problem-solving difficulties found by many researchers suggests that the observations are robust and valid. The difficulty students have in solving circuit problems seem to be due to imperfect conceptual or mental modules of circuit functioning. These imperfections can be summarized by a few buggy rules, which can be diagnosed by tests. Future effort should concentrate on refining the testing procedures and on developing instructional approaches for correcting the buggy rules.

Plans for Continuing Studies in FY85

The analyses of the data on the issues will be combined into a summary report. At the request of the CE/I (curriculum evaluation/instruction) group at the BE/E school, NPRDC will continue to assist in assessing the new course materials. There are three main thrusts in the work for FY85: students' technical concepts prior to training; diagnostic testing refinement, which will be coordinated with the ONR testing laboratory effort; and course materials prepared specifically to overcome student difficulties. Course materials will be tested for their effectiveness in reducing or eliminating faulty concepts in June-September 1985.

Work in this IR effort during FY83 examined materials from BE/E course. Data on student errors on test items were analyzed to determine how well the test diagnosed the problems students had with the concepts covered by the test items. There were high frequencies of errors on certain modules and certain types of questions. The course tests, however, were relatively inadequate for revealing the details of student misunderstanding. Therefore, there is a need to develop more systematic means for assessing student difficulties.

Objectives

This project was undertaken to (1) examine student performance and learning of basic concepts of electricity, (2) identify deficits and flaws in student solutions to test problems about simple circuits, (3) discover reasons for the difficulties students have, and (4) develop ways to overcome the difficulties. The specific objective for FY84 was to assess the student understanding of electricity and simple circuits by devising diagnostic tests. Subsequent work will develop approaches to instruction that may overcome the difficulties found.

Approach

Beginning during FY83, the tests used in the Navy's BE/E course were analyzed to determine whether problems in understanding could be diagnosed from the Progress Checks, Progress Tests, and Comprehensive Tests in use. This analysis carried over into the current effort, due in part to changes in the test items made because of our recommendations.

Based on this analysis and on an analysis by Riley (1984), new diagnostic tests for assessing student understanding of circuits (competence) and for examining the extent and type of student misunderstanding were written. One test is called the CHANGE test. Each item requires a student to report the effects of a hypothetical change in a circuit for each circuit component. The test is qualitative, that is, it requires the student to indicate whether values increase, decrease, or stay the same given the change. This test represents an improvement over the previous multiple-choice tests in two ways. First, it is qualitative only, thus eliminating the errors in calculation which are only indirectly relevant to circuit understanding and which confuse diagnosis. Second, because a student has to indicate what happens to every circuit component or measure, patterns of errors related to underlying misconceptions (the faulty or "buggy" rules) are detectable. The analysis of data from the new tests has concentrated on detecting error patterns similar to those found by Riley (1984) in her analysis of student protocols taken while students studied the BE/E materials.

The CHANGE test was first given to 46 students in the BE/E course who had completed the 14 modules that cover both DC and AC electric circuits. They were tested individually or in small groups, and were asked to indicate any questions they could not understand and to comment on the test itself by writing on the back of the pages.

A second new diagnostic test, the CAUSE test, requires students to indicate the possible causes for two observed changes in a circuit. It presents a prototypic troubleshooting task and requires students to use their knowledge of circuit functioning to identify potential causes of observed changes in circuit values.

The BE/E school changed some of the instructional modules and the format of their testing during the period during which the CHANGE and CAUSE tests were developed.

ENHANCING UNDERSTANDING OF ELECTRIC CIRCUITS¹

William E. Montague

Background

The teaching of basic electricity and electric circuits is a primary task in training for jobs concerned with electricity and electronics. The concepts of energy potential, circuits, resistance, and current, which are the prime content of such courses, are fundamental to learning about electronic devices and to maintaining such systems. Because of the value of these courses and the difficulties students experience in learning the material, research interest has increased recently. Studies have begun to examine the role of students' cognitive knowledge structures in learning and understanding, the adequacy of students' scientific concepts, and how well their concepts explain how devices work or malfunction.

The Navy teaches Basic Electricity and Electronics (BE/E) to about 25,000 trainee technicians each year. Currently, the course provides "core" knowledge and general test equipment skills before trainees attend about 20 different follow-on courses in Navy "A" schools. Similar large-scale core training is provided by the other services. The Navy course is self-paced, individualized, and structured in modules. The materials are arranged in a simple-to-complex sequence in workbooks that students study in individual carrels. The workbooks provide step-by-step programmed instruction pages and a narrative covering the same topic. Interspersed in the materials are problems to be solved along with the worked out answers. At the end of each module there is a self-test (Progress Check) with questions similar to those that will be asked on the official test (Progress or Module Test). The Module Test is presented on microfiche and processed by the Navy's Computer-Managed Instruction (CMI) system, which scores the test, records student scores and errors, and provides appropriate remedial assignments.

This course has been plagued with high attrition. Dissatisfaction with student knowledge and skills have also been expressed by follow-on schools. Attempts to alleviate these problems by revising course materials have been made many times over the last decade, but attrition and remediation rates have remained about the same. This suggests that the underlying reasons for the problems may be more fundamental to student learning and understanding than to course materials.

Recent research on the learning of scientific concepts and on problem solving suggests that the problems in such courses are due to fundamental students difficulties in learning the concepts, inter-relating them, and then applying this knowledge to observed phenomena and working devices (i.e., describing, inferring effects of changes in components, etc.). This might be due to the difficulty of the concepts, the adequacy of the instructional presentations, or inadequate student prior knowledge (or combinations of the three). More detailed analysis of student difficulties should provide a basis for more principled course revision.

¹The FY83 and FY84 results of the work under this project title (ZR000-01-042-04.014) will provide the basis for evaluating the effects of changing the delivery of the Navy Basic Electricity and Electronic Course from self-paced to group-paced/lecture-based instruction. The CHANGE diagnostic test developed for this project is being used for an ONR supported research effort to test the usefulness of adaptive testing models for instruction.

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weights lead to test scores that are maximally reliable. A new family of distribution functions that can be used to model latent ability distributions in IRT was also developed (Simpson & France, 1984). This family of distribution functions is potentially useful for a variety of applications in statistics and psychometrics.

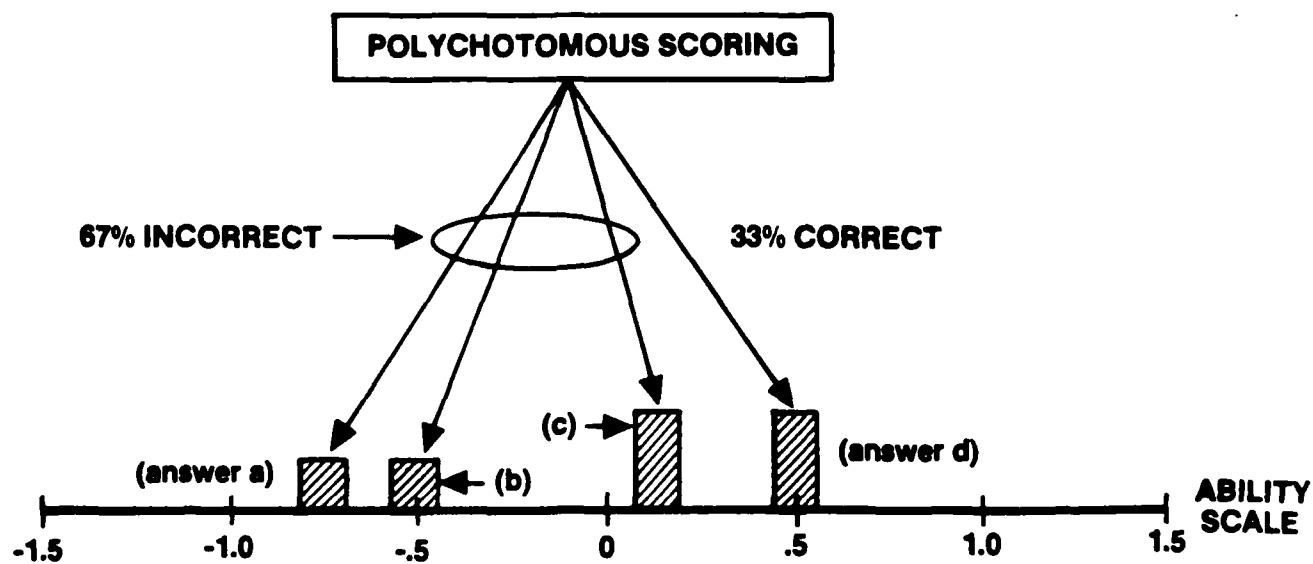
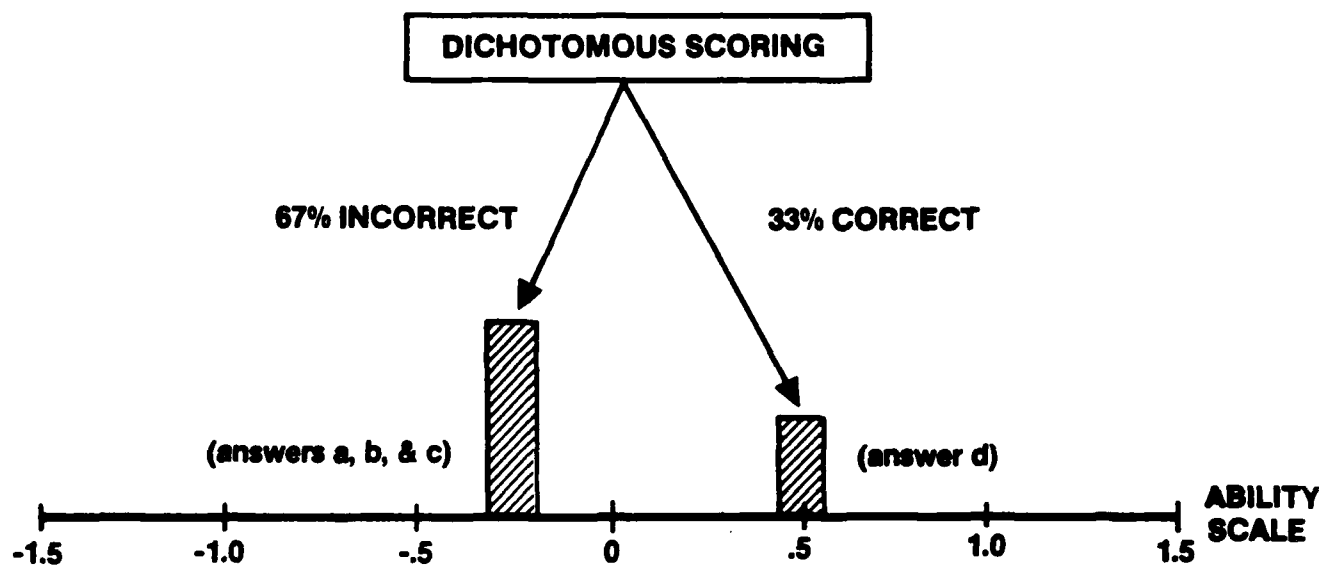
Plans

Plans for FY85 include development of a new algorithm for fitting IRT models. This new fitting procedure will require less stringent statistical assumptions than the approaches currently used. If this effort is successful, the range of applications in which IRT models can be used will increase significantly.

Benefits

If polychotomous IRT models are adopted for the calibration of test items, two immediate benefits will be realized. First, because fewer test items will have to be rejected for lack of fit to the assumed IRT model, more items will be available for the construction of new aptitude tests. Second, the use of information from incorrect answers an examinee has selected will improve our estimates of ability. It is estimated that the use of polychotomous IRT models will allow us to reduce the length of aptitude tests by about 15 percent while maintaining test reliability at current levels.

MODELS FOR CALIBRATING MULTIPLE-CHOICE ITEMS



Polychotomous scoring allows us to distinguish among people who answer incorrectly. This increases test reliability.

Figure 1. Models for calibrating multiple-choice items.

MODELS FOR CALIBRATING MULTIPLE-CHOICE ITEMS

James Bradford Sympson

Background

The effectiveness of personnel selection procedures that are based on objective measurement of individual aptitudes and personality has been well documented. Aptitude measurement, in particular, has been widely used in industry, the civil services, and the military. The Office of Naval Research has sponsored basic research on the theoretical foundations of psychological measurement for a number of years. Recently, a new type of measurement theory is leading to a variety of important advances in personnel testing. This approach to test construction, scoring, and evaluation is known as item response theory (Lord, 1980). Application of item response theory allows more precise ability estimation, especially through computerized test administration.

The basic assumption of item response theory (IRT) is that the probability of selecting a particular response to a test question is related to a person's level of ability (or other relevant personal characteristic) by a specified mathematical function. What differentiates various IRT models is the form of the mathematical function that is assumed.

Problem

Currently-used IRT models classify responses to multiple-choice test questions as either correct or incorrect. These dichotomous models make no distinction among the different incorrect responses a person might select. Information about the examinee's level of ability that could be extracted by taking into account which particular incorrect responses have been selected is lost when these models are used.

Approach

In this research project, polychotomous IRT models are being developed. Polychotomous models keep the various incorrect responses to a multiple-choice question distinct. When an examinee's test is scored, these models allow use of the pattern of incorrect responses, as well as the pattern of correct responses, in estimating the examinee's level of ability. Polychotomous item scoring increases test reliability (see Figure 1).

Progress

A research project initiated in FY81 through IR funding resulted in the development of a new polychotomous IRT model (Sympson, 1981). In FY82 and FY83, work continued without IR funding. In FY82, an improved polychotomous model was developed (Sympson, 1982). A comparison of the improved model with the model developed in FY81, and with polychotomous models developed by other researchers (Bock, 1972; Samejima, 1979), indicated that the improved model was superior (Sympson, 1983).

In FY84, IR funds were made available for development of additional procedures and models that will be needed to apply polychotomous IRT models to test data. During this period, a computer program was developed that computes scoring weights for the various response categories of multiple-choice items (Sympson, 1984). These "optimized" scoring

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Results

None of the proposed new correction procedures is adequate for Navy selection and classification problems. The procedure of Bryant and Gokhale (1972), for example, requires knowledge of the criterion variability in an unselected applicant population. This cannot be reasonably obtained in a Navy setting. The remaining procedures were similarly inappropriate or contained hidden assumptions not met in a Navy setting.

A finding of some interest was that even the simple three-variable correction formula that is often used in selection settings does not use all the information available for deriving corrected validities. A modified alternative formula was developed that was found to be superior in Monte Carlo evaluations.

Plans

Because no promising new corrections of range restriction appear to exist in the scientific literature, no further work to evaluate statistical correction formulas is planned at present.

THE TREATMENT OF RESTRICTION OF RANGE IN NAVY PERSONNEL RESEARCH

Edward F. Alf, Jr.

Norman M. Abrahams

Background

A major task in personnel research is determining the effectiveness of selection devices such as tests, interviews, or background information. While there are many ideal research designs for such evaluations, there are also many real-world prohibitions on their use.

In the ideal design, the effectiveness, or validity, of a selection device is established on a random sample of applicants. This requires that a random sample of applicants be tested, and then admitted to training or placed on the job so that their performance can be measured. The effectiveness of the selection device, which is often expressed as a correlation (validity coefficient), is indicated by the magnitude of relation between the performance measures and the scores on the selection device within this group.

In practice, a random sample of job applicants is rarely admitted to any program in the Navy. Cost, administrative infeasibility, or other factors require that only a subsample that has been screened for suitability is admitted. Since personnel researchers must evaluate selection devices based on results with these preselected samples, standard statistical corrections for the "restriction in range" of the sample are well-known and widely used. Without these corrections, the validity of the selection device for use on the whole applicant population is typically underestimated. Even with such correction procedures, validity estimates are inaccurate when certain statistical assumptions are not met. Specifically, the precise basis for selection versus rejection must be known and quantifiable.

Objective

Several new formulas for correcting selection device validity coefficients for restriction in range of the sample have recently been proposed (Bryant & Gokhale, 1972; Hsu, 1982; Linn, Harnisch, & Dunbar, 1981; Olson & Becker, 1983; Wells & Fruchter, 1970). They were mainly developed to circumvent the limitations and assumptions of conventional formulas, for example, limitations on their appropriateness when subjective criteria for which no quantitative measures are available have been used to select the sample. This research reviewed the adequacy of these new formulas for use in the Navy selection and classification setting and examined their stability by using Monte Carlo methods.

Approach

The general approach was to simulate a trivariate normal distribution for a personnel sample that had been screened on one of three variables. A computer program was written to model sampling from the trivariate normal distribution screened on one variable. Actual Navy population and Class A School sample intercorrelations were examined to find reasonable parameters to use in the model evaluation. Criteria for evaluating the corrected selection instrument validities were developed based on the absolute size of the error of estimates for the Navy population validity.

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Conclusions

The organizational implications of a thorough study of individual differences are immense. The recommendations resulting from such a study would undoubtedly have a major impact on military performance and on productivity. Whatever the reasons for overlooking individual differences in the past, there seems little justification for failing to recognize and use them now, insofar as we can, to improve the future. Implementing the ideas presented in this paper, and generating better ones, will not be easy. However, sooner or later it must be done if individuals and organizations are to reach their full potential.

No one--historian, biologist, or philosopher--has hitherto appreciated how important individuality is in human affairs . . . many have recognized that individuality is highly important. But . . . it is even more important than the most ardent advocates would have indicated. (p. 221)

Despite the enormous impact of the range of human ability, managers and their advisors--including operations researchers, human factors specialists, and even psychologists--continue to deal with a hypothetical "average" individual rather than the differences between individuals. Enormous gains would be possible if organizations were committed to identifying and optimizing these differences. Here are some important first steps that might be taken by both military and civilian organizations:

1. Personnel selection, assignment, and promotion. The attention and resources devoted to the measuring and using individual differences in finding the right persons to employ, placing them where they can do the most good, and advancing only the most capable individuals can be increased. Although the necessary processes are difficult and time consuming, the benefits can be enormous. Only when selection, assignment, and promotion are recognized as major opportunities for enhancing the organization, rather than as chores to be dealt with as painlessly as possible, will an organization begin to develop its full potential.

2. Flexible, adaptive training and job design. Each person's style of learning and working is different. In the ideal situation, such diversity will be recognized by a wide range of options such as individualized instruction, flexitime, job enrichment, and a broader choice of equipment and work assignments. Some employees prefer less rather than more job enrichment--those wishes should be respected (Lawler, 1974).

3. Individualized incentive system. The overriding feature of an individualized reward system is recognition that productivity almost always ranges upward from a ratio of 2:1 between the most and least productive workers. With explicit recognition of this fact, an organization is likely to develop an incentive program that will entice the most able workers to be maximally productive.

Since each individual has his/her own hierarchy of values, it makes sense to arrange a reward system that recognizes individual preferences. Money and recognition are obviously common rewards, but if a choice of rewards is provided, the worker and the organization will both benefit. In a comparison of four motivation systems at each of three large corporations, Miller (1981) found that the "pluralistic" approach, which recognized individual differences, was consistently superior to the others. Longer vacations, reserved parking spaces, increased autonomy, and other prerequisites are differentially attractive to different people and a menu of incentives should be offered if at all possible. The military environment is less conducive to flexibility in this matter than its civilian counterpart, but effort directed toward improving flexibility would be well spent.

The above suggestions for taking individuality into account to improve organizations by no means exhaust the possibilities. For example, as Coates and Kirby (1982) point out, some older individuals perform at a higher level than many who are decades younger--thus calling into question the wisdom of mandatory retirement.

If the job is complex, such as computer programming, electronics troubleshooting, etc., differences of several thousand percent are frequently found (Williams & Rimland, 1977). A good example of individual differences in programming ability was reported to the authors personally by a rather glum research assistant. This young man had just returned from the Southern California Programming Competition, where he and several teammates had competed against 14 other teams from UCLA and elsewhere. One single member of the UCLA team outperformed each of the other teams, each of which had at least three competitive programmers!

A formal demonstration of the programming phenomenon appears in studies of programmer performance and training. Meyer (1965) compared two methods of programmer training and found that although the means of the two groups differed by only one point (49.5 errors versus 50.5 errors), the individual error scores ranged from 30 to 70. Meyer concluded that selecting good students to begin with was perhaps more important than improving the training methods. Grant and Sackman (1966) also found very large differences in the performance of programmers. Examples from the 12 professional programmers studied are given below:

<u>Measure</u>	<u>Poorest Score</u>	<u>Best Score</u>	<u>Ratio</u>
Debug hours	170	6	28:1
CPU time	541	50	11:1
Code hours	50	2	25:1
Program size	6137	1050	6:1
Run time	8.0	0.6	13:1

The Myth of Experience

It is sometimes thought that even though people differ initially in performance, they tend to reach the same level as they gain experience. This appears to be untrue. Paterson and Darley (1936; cited in Maier, 1965), for example, studied three groups of typists with less than 1 year, 1 to 5 years, or more than 5 years of experience. The group with less than one year of experience typed an average of 39 words per minute, compared to 42 words per minute for the two experienced groups. The span of individual ability in every group, however, was immense: speed ranged from 5 to 65 words per minute (corrected for errors). Experience, therefore, did not affect the range of individual differences.

Similarly, Vineberg, Sticht, Taylor, and Caylor (1971), in a study of military technicians, found that the original differences in the aptitude of technicians were reflected in the range of performance measured 5 years later. Tiffin (1952), in discussing workers in industry, suggested that training tends to increase individual differences in performance, in proportion to the complexity of the task in question.

Discussion

It becomes clear, then, that the individual differences in performance are enormous. This fact is especially important in a world where human error can produce catastrophic consequences. As Roger Williams (1978) puts it in his book Free and Unequal,

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A NEW METHOD FOR COLLECTING PROBLEM SOLVING STRATEGIES¹

Meryl Baker

Background

One of the most essential skills in Navy maintenance is problem solving. Though the specific problems vary from situation to situation, there appears to be a class of individuals who are effective problem solvers in almost any circumstance. These people appear to draw upon a general, content-free set of strategies which facilitate problem solving ability. The purpose of this research was to explore a better research method by which to study generalizable cognitive strategies so that trainable components can be isolated. These might eventually be taught to improve the problem solving ability of Navy maintenance technicians.

Most recent research has used the method of verbal protocol analysis to gain an understanding of the mental processing which forms the basis of human problem solving behavior. In verbal protocol analysis, an experimenter records a subject's statements about the thought processes that he is using. The researcher usually uses a tape recorder, and the transcribed tape later serves as the basis for a cognitive model of the problem solving process.

The difficulty with verbal protocol analysis is that subjects may not or cannot verbalize all of their thought processes. This could be a function of both conscious and subconscious thought. In the former case, subjects may provide only what they think the researcher wants to hear. In the latter case, subjects may not be consciously aware of all the strategies they employ. Some mental processing may occur so rapidly and subconsciously that the person is unable to recall the exact problem solving process even when questioned immediately afterward. This phenomenon appears more and more frequently as we move into the high-speed problem solving engaged in by experts. Experts think so rapidly that they themselves may not be aware of the strategies they use, let alone be able to state them to a researcher for use in protocol analysis. Hence, in order to more reliably investigate cognitive processing, we need a method that does not rely on subject recall.

Approach

The present study tested the use of an inexpensive microcomputer to collect subject strategy data. Puzzles requiring only thought and logic for solution were selected. The superiority of these puzzles over, for instance, mathematical problems, lies in the fact that the solutions are obtained through inherent mental prowess rather than memory of a learned set of rules for a particular content area. In essence, each puzzle epitomized the problem solving process because its solution required thought processes which probably closely resemble those employed in most situations, including, for example, electronics troubleshooting.

The problems, as well as a method enabling the microcomputer to collect subject solution data, were programmed onto an APPLE II PLUS microcomputer. The programs

¹Work performed under the title "Generalizable Cognitive Strategies" (ZR000-01-042-06.017) was completed in FY84 and transitioned to Exploratory Development task PE62763N, RF63622801; "Generic Problem Solving."

included the puzzle text and a puzzle matrix, which was to be used by subjects as a solution board. For ease of manipulation and analysis, the data were transferred from an APPLE II PLUS microcomputer to a VAX 11/780 computer.

Results

The rich data set resulting from this effort will be used in future research to form the basis of a cognitive model of solution strategies, one important aspect of problem solving. Though this model and the instructional strategies to be derived are the ultimate goal of the overall research endeavor, the present accomplishment of successfully collecting subject strategy data via the microcomputer adds significantly to the field of cognitive research. It presents a cost effective means for collecting and analyzing subject protocol data. In future research efforts, protocol data collected via this method will be compared with verbal protocol data. If equal or better quality data result from the new method, then cost and time savings, and increased sophistication in subject comparisons through computer data manipulation, would support this method as an appealing alternative to verbal protocol collection and analysis.

COGNITIVE AND EMOTIONAL PROCESSING

Barbara McDonald

Background

Psychological research in the past has typically separated the study of cognition (e.g., learning, memory, skilled performance) from the study of emotion. Although scientist and lay person alike would agree that emotion plays a big part in human learning and task performance, and that task performance plays a big part in emotions, psychologists have not studied them as inseparable processes. Especially in this age of high technology, where rational problem solving and pragmatic decision making represent the popular mode of thinking, emotion has often only seemed to complicate the important issues in cognition (e.g., in research on the development of expert systems and in research on reasoning about complex systems). As a result, emotion has been largely left out of the study of thinking and learning.

In spite of the difficulties of incorporating the relationship between cognition and emotion into a scientific analysis, there has been a recent upsurge of interest within a diverse group of studies. For example, studies are now investigating health behaviors (people who express their fears about illness report much less physical pain, Leventhal, 1982), attitude change (people have a difficult time changing their attitudes even when concrete evidence supports a different position, Zajonc, 1980), and mood-dependent recall (people remember information better if they are in the same mood during learning and recall, Bower, 1981). These studies all suggest the importance of understanding emotion to the understanding of learning and performance. However, up to this point, researchers have not looked at what actually happens during learning and performance when emotions are involved. Research addressing this area would be of direct relevance to the study of military tactical performance because military tasks are often performed under frustrating, anxiety-producing, and potentially life-threatening conditions.

Objective

The purpose of the present research is to investigate the mutual influence of emotion and cognitive processing on learning and subsequent performance. The objective of the first year was to develop a method of observation for the study of the influence of emotion and cognition on learning and task performance.

Approach

The method to be developed had to meet several important conditions: First, an experimental scenario was needed in which ongoing behavior could be monitored. This suggested a naturalistic approach in which performance data and emotional reactions could be collected simultaneously during task performance. At the same time, it was critical to conduct the experiment under similar conditions for each subject. It was also determined that a task should be observed at different levels of difficulty under normal conditions as well as frustrating (emotion-producing) conditions. Finally, it was important that the task be realistic and absorbing for the participants. By including all of these conditions, an attempt was made to create a task setting in which the key elements were adaptation and adjustment to task demands and to the emotions resulting from task performance.

Results

The experimental task which was developed involves observation of experts and novices playing a computer-based game of military tactics. The eventual participants in the study will be instructors and students at the Fleet Combat Training Center in San Diego. The instructors will serve as experts because they use the computer-based game in their courses as well as teach the information used in the game; the students will serve as novices.

Each subject will be studied individually in three separate conditions. In the first session, the game will be played under normal conditions. In the second session, the game will be modified to include frustrating events (buttons will not work as usual and the timing will be off on a random basis) and anxiety-producing events (false information and unexpected events). The third and final session will repeat the normal condition. For all three sessions, the games will be played at basic, intermediate, and advanced levels of difficulty.

The computer will collect data on subject skill strategies and the timing of strategy use. All three sessions will be tape-recorded. The role of the experimenter will be to encourage the player to talk about the task as he is playing the game and to develop an atmosphere in which the player feels free to express any feelings or thoughts he might have. The experimenter will probe the player for strategy information and engage in conversation if the player wishes to discuss something. In this way, observation of emotional reactions can be done unobtrusively and simultaneously with performance of the task. Thus, a verbal report by subjects after the games will not be required.

The method was used on several subjects at the end of FY84 in order to test its feasibility. The task and the method of observation proved to be very successful. The issues of primary interest were (1) whether the game could be played while the subject verbalized thoughts and feelings, (2) whether the computer-based game was realistic and could produce identifiable emotion, and (3) whether skilled and unskilled task performers could experience emotion and still perform the task. The new research method appears to provide the needed situation and information.

In FY85, the initial study using the new method will be completed. After the data analysis, a more formal study will be proposed in which more sophisticated measures will be used (e.g., more sensitive indicators of emotional reactions, including physiological measures).

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PROCEDURAL TASKS: WILL TEACHING THEORY ENHANCE RETENTION?¹

Paula J. Konoske

John A. Ellis

Background

Recent surveys have found that most military tasks are procedural (Van Kekerix, 1983; Tarr, 1983; Fredricks, 1981), and other research has found that procedural tasks are the most important type for Navy mission readiness (Campbell, O'Conner, & Peterson, 1976). That is, Navy personnel in technical ratings must maintain high levels of procedural skills and knowledge.

Procedural tasks consist of an ordered sequence of steps or operations performed on a single object or in a specific situation. Procedural tasks involve few decisions and are generally performed the same way each time. They vary in the amount of planning required, the number of steps and subprocedures, the amount of cueing built into the task, the number of decision points, whether or not the order of the steps can vary, and whether the goals of the task are internal or external to the task, system, or situation (e.g., operation vs. maintenance).

Unfortunately, procedural tasks are frequently not well retained (Schendel, Shields, & Katz, 1978; Vineberg, 1975; Ellis, 1980; Hurlock & Montague, 1982). One possible reason for this problem is that most instruction for procedural tasks is "lean." That is, procedural tasks are most often taught as a linear sequence of steps with a single top-level goal. The instruction typically contains little explanation ("theory") about the system or situation and how the steps interrelate. Students are usually required to memorize procedural information. A possible solution to the forgetting problem which typically occurs after instruction is to design instruction that makes the task more easy to remember. This project investigated the effects of qualitative explanations or elaborated instructions (the "theory" behind the procedure) on learning, performance, and long-term retention.

Approach

Qualitative explanations or elaborated instructions are what Navy instructors and training developers are talking about when they use the word "theory." Because of the controversy in Instructional Systems Development (ISD) and Navy technical training over how much theory to give students, it is important to determine when and how much theory should be presented for specific types of procedural tasks. Adding theory will lengthen training, but more theory may enhance learning and retention. The scientific rationale for teaching theory is that qualitative explanations help learners build mental models (concrete mental representations) of systems and tasks. Providing students with supplemental explanations sometimes facilitates learning and retention of procedural and complex rule- and principle-based tasks (Gentner, 1980, 1981; Smith & Goodman, 1982; Tourangeau & Sternberg, 1982; Kieras, 1981; Sturgis, Ellis, & Wulfeck, 1981).

¹Some of the work undertaken in FY84 under the project title "Cognitive Factors in Learning and Retention" (ZR000-01-042-06.027) will be used for Advanced Development tasks PE63720N; Z1772-002: "Functional Context Training," and PE62763N; RF63522801: "Classroom Instructional Process."

Because recent reviews of the scientific literature revealed that very little work has been done on procedural tasks and that various authors define qualitative explanations, analogies, etc., and procedural tasks in different ways (Stevens & Steinberg, 1981; Smith & Goodman, 1982), an operationally defined taxonomy of types of qualitative explanations was developed. Linear types (nonqualitative presentations) provide the student with inventory information about what to do with the system or in the situation. Structural explanations provide information about how or why the system or situation is constructed. Functional explanations provide information about how or why the system or situation works. After the types of explanations were identified, the research relevant to each type was reviewed, and the kinds of explanations necessary for specific procedural tasks were identified. Because procedural tasks differ in many ways, the initial part of this process involved identifying types of procedural tasks. Four different "classes" of tasks were identified: (1) operator tasks, (2) maintenance/repair/assembly tasks, (3) paper-based tasks, and (4) tasks which include locating information or objects. Finally, a matrix, shown in Table 1, combining tasks and explanations was developed.

Table 1
Type of Procedural Task and Type of Theory
That May Improve Retention

Type of Procedural Task	Type of Presentation				
	<u>Linear</u>	<u>Structural Theory</u>		<u>Functional Theory</u>	
		How	Why	How	Why
Operation	*	*	*	+	+
Maintenance					
Repair	*	+	+	+	+
Assembly	*	+	+	+	+
Paper-based					
Filing Forms	*	+			
Formatting documents	*	+	+	+	
Locating information or objects	*	+	+	+	+

Note. Qualitative explanations (theory) can be direct or analogical.

* Indicates that a theory can be applied to the procedure.

+ Indicates that teaching the theory behind the procedure may facilitate performance/retention.

Table 1 indicates our hypothesis for each type of task and explanation. For example, we predict that the "how" type of structural explanation will facilitate retention and performance of maintenance procedures. (Procedural tasks are always taught by a linear presentation whether additional explanations are presented or not.) In addition, when functional explanations are given, they sometimes include structural information. Thus, all types of explanations would be necessary for some procedural tasks while others would

require only one or two types. For example, operating the brakes of a car does not require knowledge of how the brakes are structured, but it does require linear information about the effect of pushing your foot on the pedal as the cause of the car stopping. Repairing the brakes of a car, however, requires knowledge about how the brakes are put together and the cause-effect function of the parts.

Research Plans

We proposed to conduct two experiments in FY85 to test the hypotheses generated by Table 1 about what types of explanations should be given with the various types of procedural tasks. In general, the experiments will examine the effects providing various types of explanations on the learning, performance, and retention of procedural tasks. We are currently planning to look at assembly tasks. We may also vary the quality of the theory presented to determine the characteristics of good versus poor explanations. The goal for FY85 is to complete the experiments and prepare the appropriate journal article(s) and/or technical report(s).

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ACQUIRING SKILLS FROM WORK EXPERIENCE¹

Robert F. Morrison

Background

This research sought to model the learning from work experience that prepares people for successful performance in their career roles. Such a model could aid the design of developmentally oriented career patterns that optimize learning. Approaching career development from the perspective of experiential learning has been overlooked in theory, research, and application. The past emphasis has been on formal off-the-job education and training, with some recent emphasis on the supervisor-subordinate (mentor) relationship. Recent studies have indicated that formal education and training account for only about 20 percent of work-related learning, with the remainder accruing from experience (S. Campbell, personal communication, January 14, 1985).

Approach

The research contained three general areas of concentration: (1) a summary of theory and technology required to understand and apply experiential learning, (2) a new theoretical model, and (3) the collection of data for a test of the model and the development of measurement techniques.

Results

Current Theory and Technology

A review of the literature on career development through experiential learning revealed very little theory or application of direct relevance. A survey of related constructs and technologies identified the following three broad areas with potential relevance:

1. Human resources management. This scientific literature on career paths and patterns proposes use of subjective job titles and the mathematical modeling of historical data. The methods do not consider learning as a central theme and thus do not allow for the design of new developmentally oriented career patterns within dynamic work environments.

2. Learning and developmental theory. Many concepts from the huge literature on learning theory appear to apply to adult development during their careers. It is necessary, however, to use mega-extrapolation from the time frame of minutes or days used in the theories to the time frame of many years that comprise a career. The theories that are robust enough to hold up under time-frame expansion are instrumental learning as interpreted by the social learning theorists, vicarious learning, learning hierarchies, and mastery learning.

¹The results under the project title "Acquiring Skill from Work Experience" (ZR000-01-042-08.023) have led to the proposal of new FY87 6.2 level research in officer career development. That research would look at both the optimum length of operational (sea), quasi-operational (sea-related shore), and nonoperational (unrelated shore) tours and the sequences of tour assignments required to produce effective operational and nonoperational commanding officers. Support for such a proposal has been received from OP-13.

3. Job/role analysis. A great deal of research on job analysis has defined jobs in terms of specific formal duties, tasks, and task elements. What is learned from experience, however, is frequently complex and subtle, so most of these approaches are inadequate for the study of experiential learning. The term "job" must be reconceptualized in terms of the various roles performed at work. Many of these informal or interpersonal roles are untapped by traditional job analyses, require a great deal of learning that does not take place in a formal classroom, and are essential to successful career development.

Proposed Model

A new model has been designed during this research. It prescribes the constructs that must be considered to enhance the development of work-related knowledge and skills throughout a career's work experience. The model provides a framework for a technology that can integrate experiential learning into the broader context of adult career development.

Underlying this new model is the notion that career experiences can be planned in logical sequences so that learning is maximized. In order to plan an experience sequence, new technology for analyzing jobs in terms of roles and role-behaviors must be devised. Career paths can then be designed so that individuals have maximum opportunity to learn from experience the behaviors necessary for the various roles encountered throughout a career span. Based partly on the concepts from learning theory mentioned above, it is proposed that the ideal process of career development would be a flexible hierarchy of work experiences, each increasing the likelihood of success at the next level and building the skills needed to perform well in a set of target career roles. Some roles are unique to entry-level positions; other roles become more complex as the individual transitions from one position to another. Still others roles are prevalent in more senior positions.

Pilot Study

An exploratory field study was undertaken to enhance the theoretical work, support or modify the model, and initiate the technology required to operationalize new concepts. Interviews with Navy officers determined some of the various roles they must perform, the knowledge and skills needed to perform them, and the career experiences that gave them the opportunities to learn necessary behaviors. This information provided some initial support for the experiential career learning model. Concomitantly, some factors that should be considered in the modification or revision of Navy officer career patterns were identified. Use of these factors could make learning faster, more thorough, and more focused on those skills that are required for present and future job performance.

MODELS OF HUMAN PERFORMANCE WITH APPLICATION TO DECISION AIDING¹

Frank L. Greitzer

Ramon L. Hershman

C. Rogers Saxon

Background

The nature of today's threat and the sophistication of modern combat systems impose heavy burdens on Navy personnel. While innovations in automation are impressive, they do not obviate human decisions; rather, operators must process more information with less time and error than ever before. Thus, it is essential that designers of combat systems and decision aids consider the cognitive skills of human operators. Data are required on the kinds of decision strategies they invoke, their limitations in processing information, and the effects of increased workload demands. Computer support can then be applied more appropriately to enhance the decision-making process.

Approach

Detecting a Change in Target Location

A generic surveillance task was selected to serve as a testbed for research on modeling cognitive processes and evaluating various techniques for computer aiding. Briefly, the task is as follows: The decision maker must decide whether a target is at a previous fix or has moved to a new location offset by a known distance and a random angle. The observer views a sensor display that shows a noisy sample of N reported locations of the target. The noise has the circular normal probability density, and each datum encodes the target's reported x, y coordinates. It is assumed that the target is stationary at the time the data are observed and that all directions of movement are equally likely.

In the most straightforward version of the task, the data appear as points on a CRT. Figure 1 shows two typical displays. The decision maker is informed that the target was originally fixed at the center of the circle but may have moved R units to the circumference. Clearly, the target has moved in the right-hand display but not in the left-hand display. The decision maker sees only one such display and must infer whether or not the target has changed location. Of course, the task is more difficult for a smaller sample size (N).

Human performance data and theoretical results for a mathematically optimal processor have been described earlier (Hershman & Greitzer, 1982; Greitzer & Hershman, 1983). In this FY84 effort, decision times were measured for alternative display representations and varied sample sizes. However, attempts to quantify the observer's specific information processing were unproductive. Decision time was virtually independent of N , contradicting the notion of a serial processor that computes the optimal

¹Results from the project titled "Models of Human Performance with Application to Decision Aiding" (ZR000-01-042-09.022) have been incorporated into Exploratory Development Task PE62757N; SF57525601: "Decision Aiding in Combat Systems."

In other words, the people who probably will not reenlist appear to be dissatisfied with their recent duty location and assignment while those who plan to reenlist are more concerned with holding on to what already exists. The trends are similar for those with more years of service.

In sum, the demographic and incentive-preference patterns reveal some differentiation between low- and high-reenlistment-prone personnel within each years-of-service category. As years of service increase, demographics become less discriminating but the pattern of incentive preferences persists. Moreover, in all cases, the high-reenlistment-prone respondents were highly sensitive to maintaining retirement benefits and promotion potential at no lower than current levels. The low-reenlistment-prone respondents also wanted inducements that exceed current levels in terms of better duty assignments or higher economic rewards, the latter becoming more desired as years of service increased.

Optimal Promotional Themes

From the lists of 28 reasons for reenlisting and 28 reasons for separating, enlisted personnel selected their most salient 6 reasons in each category. In the analysis of segment differences, six very popular items were eliminated and an optimal package of three themes was selected. For example, for 0-5 years of service, the three themes of "good pay," "travel," and "more skill training," reached 85 percent of the respondents.

Good pay and travel incentives appeared consistently in the other years-of-service categories, but the groups differed on the third theme, skill training. Skill training was replaced by good advancement opportunities (6-10 years of service), duty assignment (11-14 years), and proud to wear the uniform (15+ years). Using these optimal packages rather than simply the three most popular themes improved audience reach by a maximum of 5 percent. A similar analysis was conducted with the separation reasons.

Optimal Incentive Menus

Private sector employers are taking action to cut the amount they spend on employee benefits in 1985, but workers may find that these fewer dollars stretch farther. One method companies use to help employees get more value from health insurance, life insurance, and other benefits are the new "flexible" benefits plans. According to an Associated Press report, 9 percent of the companies surveyed already had flexible benefit plans and 37 percent were considering them.

One objective of the present study was to determine an optimal menu of reenlistment benefits that might comprise a type of flexible benefit plan for the Navy. By "optimal menu" is meant a set of inducements that provides the maximum net increment in likelihood of reenlistment above the status quo, after adjusting for the cost of the inducement. A potential reenlistee can select a single inducement (in addition to the "standard" package of inducements) that appears best for him or her.

There are two criteria for selecting an optimal menu. First, the optimal subset results in the largest net gain in reenlistment probability, given that a respondent chooses the inducement that most increases his likelihood of reenlisting. Second, the cost of the incentives is minimized. Unfortunately, it is very difficult to place a dollar value on the cost of each incentive and the trade-off between that cost and its negative effect on the incremental probability of reenlistment. For the purposes of demonstrating the potential of this optimal menu technique, three Navy officers responsible for enlisted retention, working as a team, rated each of the incentives on a "difficulty-of-implementing" scale.

5. Demographic information such as respondent age and education.

Analyses and Results

Segmentation

Prior research and a preliminary analysis led to the selection of two segmentation variables: years of service and proneness to reenlist. Four years-of-service categories were created based on the selective reenlistment bonus categories. Proneness to reenlist was defined as the average rating the respondent gave to the 35 reenlistment incentives. Within years-of-service intervals, respondents were split into two groups depending on whether their proneness to reenlist was above or below the median for their group. This segmentation plan led to eight groups.

Demographics

Within each year-of-service category, a discriminant analysis was performed to predict high versus low proneness to reenlist. For the group with 0-5 years of service, the results for demographic segmentation show that low proneness to reenlist was associated with higher pay grades, higher AFQT test scores, single marital status, Caucasian race, submarine duty, and the perception that similar civilian jobs pay more than the Navy. In other words, during the early years of Navy service, the bright, single, white enlistee appears to be less prone to reenlist. For those who had reenlisted at least once, demographic differences between personnel with low and high proneness to reenlist were less discernable. The major effect of demographic variables appears to occur in the first 5 years of service.

Programs and Policies

The pattern of preferences for reenlistment incentives was examined by combining the 35 reenlistment incentives and the seven other policies. These 42 variables were normalized around each respondent's own mean and standard deviation to allow analysis of relative preferences for the 42 policies. A discriminate analysis of low and high proneness to reenlist using the 42 variables as predictors was performed separately by years-of-service categories.

The major distinctions between the low and high reenlistment groups for personnel with 0-5 years of service were as follows:

Low proneness to reenlist was associated with high preferences for guaranteed:

1. First choice of duty location.
2. First choice of duty assignment.
3. Permanent duty location of up to 5 years.

High proneness to reenlist was associated with greater sensitivity to:

1. Lack of a reenlistment bonus.
2. Delay of retirement to age 60.
3. Increased age for retirement eligibility.
4. Reduced chances of promotion.
5. Availability of a firm civilian job.

APPLICATION OF MARKET SEGMENTATION TO NAVY RETENTION ISSUES

Susan Hearold

Background

Market segmentation is concerned with individual or group differences in response to products. It provides guidelines for a firm's marketing strategy and resource allocation among markets and products. The presumption is that if consumer response differences exist, can be identified, and are reasonably stable over time, the firm can increase its sales and profits beyond those obtained by assuming market homogeneity.

The application of market segmentation is not limited to consumer goods. In keeping with marketing's broadening scope and the position that many forms of human exchange belong within the domain of marketing, social products increasingly appear as foci of marketing thought. Market segmentation has been applied to such diverse fields as the development of nutrition programs in India, the marketing of zoos, and the specification of strategies for economic development in Columbia.

Approach

This study used several market segmentation procedures to analyze the responses of Navy enlisted personnel to reenlistment incentives. The primary dependent measure, intention to reenlist, is analogous to a preferred consumer product measure, intention to purchase.

Sample

The survey sample was a representative group of all Navy nonreserve and rated enlisted personnel whose reenlistment decision was due within the next 12 months. The population was stratified by rating and number of enlistments, and a proportional sample was selected. Surveys were sent to 2825 personnel. Of those, 1309 usable questionnaires were returned (a 46% return rate).

Survey

The questions were presented in seven sections, five of which were used in this market segmentation study:

1. Present reenlistment intention rated on a 0-10 probability scale indicating current likelihood of reenlisting.
2. Thirty-five reenlistment incentives (e.g., pay, shore duty), each rated on the same 0-10 point probability scale indicating likelihood of reenlisting if just this one change were made in current benefits.
3. Seven reenlistment policies that were not necessarily reenlistment incentives (e.g., retirement possible after 10 years), each rated on the same 0-10 point scale.
4. A list of 28 reasons for reenlisting and 28 reasons for separating, from which the respondents were asked to pick 6 from each group.

Progress

This independent exploratory development project was formally initiated on 29 March 1983. The conceptual and developmental work were completed through the end of FY84. The basic real-time simulation model has been designed and implemented on a TERAk. It provides for player interaction and responds to commands to employ ship defense measures. The player query, response handling, and performance evaluation processes have been designed and implemented, and the platform and weapon system characteristic data bases have been completed. The development of the simulation model and the query/response features has been completed and the threat and ownship data bases have been filled. Formative evaluation has been conducted at NPRDC and at the Fleet Combat Training Center, Pacific (FCTCP).

The tactical decision trainer project (PE63720N) initiated in FY85, aimed at providing training at the unit level in multiship, multithreat environments, is building upon the training concepts developed in the single-ship, single-threat (AAW) training situations provided for in the self-defense tactical trainer. Additionally, the SDTT system will be implemented at FCTCP to supplement TAO training in a manner that has proven interesting and enjoyable for the students.

Table 1
Features of the SDTT Player-Computer Interactions

Program Features
<u>General:</u> <ol style="list-style-type: none">1. Written in UCSD Pascal for the TERAk.2. The U.S. Navy surface combatant is selectable by the player or can be randomly selected by the program (all current/projected ship classes are modeled).3. The threat platform is selectable by the player or by the program (all ASCM threats in the TAO matrix are modeled).
<u>Before the Real-time Wargame:</u> <ol style="list-style-type: none">1. Queries the player on data associated with the selected U.S. Navy ship or threat, if known (weapons carried, emitters associated, launch ranges, weapon characteristics, etc.).2. Records player responses.3. Provides limited tutoring for incorrect responses.4. Simulates the operation of threat emitters in prelaunch or launch condition.
<u>During the Wargame:</u> <ol style="list-style-type: none">1. Generates up to three different ASCMs aimed at the U.S. Navy ship.2. Simulates ASCM flight profiles and emitter employment during flight.3. Permits the player to enter commands to defend his ship, including the employment of surface-to-air missiles (SAMs), BPDMS, CIWS, chaff, and SLQ-32 deception and jamming, if the selected ship is so equipped.4. Graphically presents engagements, using symbology and track numbers similar to the Navy Tactical Data System (NTDS).5. Provides continuously updated alphanumeric data on signal, target, weapon, and command status.6. Computes outcomes of Hardkill weapon engagements with ASCMs.7. Computes effectiveness of Softkill (electronic countermeasures) system employment.8. Displays engagement results graphically and alphanumerically.
<u>After the Wargame:</u> <ol style="list-style-type: none">1. Evaluates the defensive measures taken by the player (calculates the cumulative effects of the player's actions on the probabilities that the ASCMs hit the ship).2. Scores the player on his responses to queries and the tactical employment options used in the wargame.

THE SELF-DEFENSE TACTICAL TRAINER¹

David W. Anderson

Background

The tactical proficiency of naval officers has been an issue of major concern in OPNAV for many years. Present tactical training includes courses and team training at Fleet Combat and ASW Training Centers and infrequent at-sea or inport multiship exercises. Tactical action officer (TAO) courses are extraordinarily rigorous and require memorization of a tremendous amount of data on platform and weapon system characteristics and tactics. These include ownship sensor and weapon characteristics, threat platform sensor and weapon characteristics, antiship cruise missile (ASCM) employment tactics, and employment of "Hardkill" (target destroyed) and "Softkill" (target decoyed or jammed) ASCM countermeasure systems. There are few means to refresh and reinforce the knowledge after the TAO returns to his ship. Consequently, there has been significant high-level interest in revitalizing tactical training through microcomputers and computer-assisted training (CAI) techniques, both to improve proficiency and to move more training aboard ship.

Objective

The objective was to design and develop a prototype microcomputer-based self-defense tactical trainer (SDTT) to exercise and test an individual officer's threat assessment capabilities, tactical knowledge, and reactions. The exercise and test were to be performed in real-time or near real-time against a computer-generated ASCM threat. Such a system could be used for initial training in the schoolhouse and, because microcomputers are portable, for refresher training onboard ships or at Fleet Training Groups. Primarily, this software development was undertaken in anticipation of transition to an advanced development effort in tactical decision training.

Approach

An interactive CAI/computer wargame simulation program was designed to run in UCSD Pascal on the TERA microcomputer. The program consists of procedures to select a USN platform and ASCM; draw and refresh the screen and symbols; generate appropriate electronic signals; handle the missile and ownship graphics; provide alphanumeric data on signal, target, and weapon status; and compute outcomes of AAW missile, close-in weapon system (CIWS), and basic point defense missile system (BPDMS) engagements with ASCMs. The program also computes effectiveness of electronic countermeasures such as chaff and SLQ-32 jamming and deception. CAI techniques are used to query the player interactively on ownship and threat characteristics and tactical aspects of the scenario presented, to score responses, and to provide feedback on the simulated tactical measures the player uses in defending his ship. The system is user-friendly enough to allow the officer with very little computer experience to set up and "play."

Table 1 describes features of the SDTT and illustrates the approach and player-computer interactions.

¹Work under the project title "Self-Defense Tactical Trainer" (ZF66-512-001.008) has been transitioned to Advanced Development task PE63720N, Z1772: Tactical Decision Training.

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Liang, T. T. (July 1984). Network formulation of multiple-criterion problems for developing an integrated personnel distribution system in the Navy (NPRDC Tech. Rep. 84-49). San Diego: Navy Personnel Research and Development Center.

Results

An empirical model was developed in which the transportation section of the network was developed to handle policies at the operational level and the transshipment section of the network was developed to handle policies at the manpower planning level. The special contribution of this effort is the development of a dynamic process to generate and to integrate all possible manpower goals into the transshipment section of the model. The policy objectives are optimized preemptively one after another by using the sequential elimination method or the composite objective function. This work supports the theoretical development of the individual research (see Liang, 1984).

Applications

The methodology was applied to a 6.3 project (personnel assignment system) to develop an automated personnel allocation and assignment system for the nonskilled enlisted personnel. It was the first successful attempt in developing an automated policy planning and operation system for personnel assignment in the Navy. The Navy's assignment and allocation offices are in the process of implementing the new system. This system will be expanded to handle skilled enlisted personnel as well. In addition, the work is being applied to other 6.2 and 6.3 projects related to career management planning, personnel classification, and sea/shore rotation.

Research Potential

Although the multiple criterion optimization technique developed from this effort is sufficient for existing projects, more research is needed to solve more complex problems. In particular, additional research is needed to (1) improve measurement of the trade-offs among policies, (2) increase the flexibility of the technique to incorporate more policy objectives and constraints, and (3) evaluate the impact of various policies.

MULTIPLE CRITERION OPTIMIZATION TECHNIQUES¹

Timothy T. Liang

Background

Accession, promotion, rotation, and attrition frequently require the Navy to redistribute its personnel to major units and reassign individuals to jobs. In matching people to jobs, the decision makers consider numerous rules and regulations on people-jobs eligibility. A person might be eligible for many jobs and a job might be suitable for many people. However, a person can only be assigned to one job and the Navy assigns people according to current policies. There are many microlevel policies involved: For example, the Navy has always tried to match personnel skills with job requirements to maximize resource utilization. Navy policy also tries to minimize personnel moves from one location to another, thus saving moving expenses. The Navy also tries to assign personnel to the location of their choice, when possible, to satisfy individuals and to increase retention. With these multiple and often conflicting policies included in the decision process, it is unlikely that the decision makers can satisfy all policy goals and requirements without a systems approach.

Recently, the Navy has been increasingly concerned about manpower planning, and macrolevel policies have been introduced to improve aggregate manpower distribution. Manning (percentage of positions filled) is frequently used to measure manpower balance. Some policies are directed to balanced manning between the Pacific Fleet and the Atlantic Fleet; other policies are developed to create a manning ratio for sea and shore duty. The decision makers assigning people to jobs within the context of these macrogoals are already so burdened by policies at the microlevel that making optimal decisions is difficult. Research is needed to develop a large-scale model to study multiple-objective decisions.

Multiple criteria models have been a subject of accelerated interest during the past decade. The major efforts focus on algorithms to estimate the numerical weights of multiple policies. Conventional mathematical programming approaches, however, are not capable of efficiently solving large scale problems such as the Navy's personnel distribution problems, particularly for those problems that require integer solutions. Remarkable technological breakthroughs in network optimization during the past few years have enabled routine and efficient solutions to large and complex planning problems. They provide the opportunity to develop a network formulation for multiple-objective problems. The Individual Research effort of this project in FY83 developed a technique that demonstrated the feasibility and capability of developing a network approach to study the large scale multiple-criterion optimization problems.

Objective

The purpose of the current IED effort is to use the technique developed under previous Independent Research and the data from the Navy's personnel assignment problem to derive an empirical model to help decision makers assign personnel to jobs in accordance with multiple and conflicting policies.

¹The results of work under the project title "Multiple Criterion Optimization Techniques" (ZF66-511.013) have influenced work in three FY85-funded efforts: (a) PE63707N, Z1770: Personnel Assignment System, (b) PE62763N, RF63-521-004-031: Career Management Planning, and (c) PE99000N, C0073-002.02: CLASP System Development.

INDEPENDENT EXPLORATORY DEVELOPMENT (IED) PROGRAM

The Independent Exploratory Development (IED) Program at Navy Personnel Research and Development Center was initiated in FY76. Work in this funding category is intended to develop or evaluate basic research with a focus on specific military problem areas. IED work units for FY84 and FY85 are listed in Table 2. Several of the FY84 research efforts will be transitioned to FY85 projects in the areas of tactical training (see Anderson, p. 38), personnel assignment and career planning (see Liang, p. 36), and authoring instructional materials (see Chang, p. 46). Selected work conducted within these units during FY84 is described in the remainder of this section.

Table 2

Independent Exploratory Development Work Units for FY84 and FY85

62766N	Project Title	Principal Investigator	Funding in \$K	
			FY84	FY85
ZF66-511.013	Multiple Criterion Optimization Techniques	Dr. T. Liang AV: 933-2371 Code 61	40	15
ZF66-512.008	Self-defense Tactical Trainer	CDR D. Anderson AV: 933-7100 Code 05	26	0
.009	Application of Market Segmentation to Navy Retention Issues ^a	Dr. S. Hearold AV: 933-2081 Code 71	27	0
.012	Alternative Military Manpower Supply Methodologies ^a	Dr. J. Borack AV: 933-2371 Code 61	50	0
.014	Development of Computer-based Writing Aids	Dr. F. Chang AV: 933-6434 Code 51	15	0
.015	Interfaces for Combat Decision Support	Dr. F. Greitzer AV: 933-2081 Code 71	0	90
.016	Impact of Statistical Process Control	Dr. L. Broedling AV: 933-6620 Code 52	0	10
.017	Development of Graphic Design Aids	L. Weitzman AV: 933-6242 Code 501	0	50
			158	165

^aCompleted in FY84.

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that target that will reach ownship the soonest." Note that this strategy compels the operator to integrate both target range and speed in establishing firing priorities. An alternative, range strategy, is simply to "Always fire at the closest target." Since the range strategy requires only one attribute for its implementation, its processing rate should be higher.

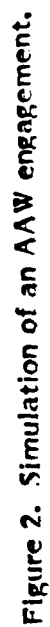
Our experiment manipulated two factors: strategy instruction and workload. In one condition, an experienced air intercept controller was asked to prosecute targets as usual. In another condition, he was explicitly instructed to use the vulnerability strategy. Workload was varied by using two target arrival rates.

A mathematical model based on the target rankings for range and vulnerability was developed and tested. Using only two parameters, the model makes predictions for the probability that the j th-ranked of k targets (based on either presumed strategy) will be the one selected for firing. It was found that the operator's normal processing mode was a range strategy, although he could adopt the more complex vulnerability strategy when so instructed. However, despite its defined empirical optimality, the vulnerability strategy led to poorer performance (increasing the threat to ownship), presumably due to its greater processing burden. There was no evidence of a shift in strategy due to workload; rather, it seems that increased workload limited the depth of processing to which the operative strategy was pursued.

Another experiment briefly tested various aids. An operator performed either unaided or was assisted by the computer-driven display that showed: (Aid 1) the single most threatening target; (Aid 2) the most threatening fast, medium, and slow target choices; or (Aid 3) the three best choices regardless of speed. It was presumed that Aid 1 would be most effective; the other aids were expected to assist the operator but lead to an increased processing demand. The result, however, showed that compared with the unaided condition, the aids reduced ownship vulnerability by 31, 58, and 78 percent respectively. Thus Aid 3 was best, permitting the operator to prosecute targets at a high rate with minimal loss in decision quality. Although Aid 1 had been designed for optimal target selection, it promoted dependency on the computer and reduced the output rate.

Conclusions

1. The operator's adoption of a simple range strategy is interpreted as an optimal use of nonoptimal resources. It is thus a good example of well-advised coping with formidable processing demands and confirms in a dynamic decision task the earlier findings of Rigney and DeBow (1967).
2. Strategies used by "experts" are not necessarily optimal. They may not be the best guidelines for automated algorithms.
3. Detailed data collection and rather simple mathematical models (based only on rank-order information) are useful in making inferences about an operator's threat assessment strategies.
4. Decision aids that promote the user's dependency on the computer should be avoided. User-computer collaboration is a more effective approach, but it requires increased attention to human skills and limitations.



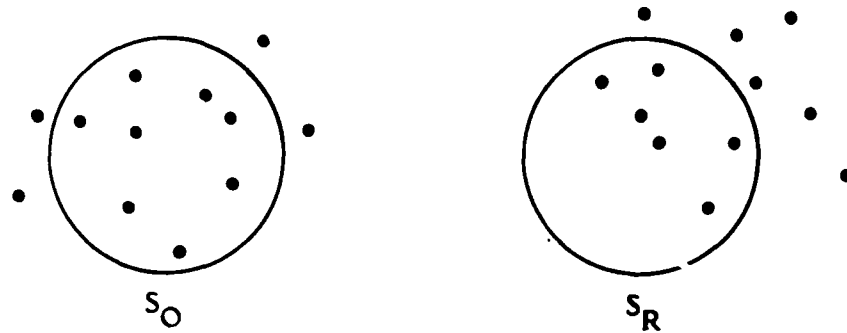


Figure 1. Two typical displays with $N=12$. In the left-hand display, the target has not moved, and the reported positions cluster around its original fix at the center of the circle. In the right-hand display, the target has moved to the circle's circumference at an angle of approximately 45 degrees.

decision statistic--namely, the distance from the origin to the centroid (or center of gravity) of the displayed data. Efforts to aid the observer by displaying the centroid or the criterion distance were ineffective. It was concluded that an observer's solution is by and large perceptual, rather than cognitive; that is, figural pattern processing is invoked rather than computational algorithms. Accordingly, the surveillance task was deemed unsuitable for the planned investigations and a different context for the research was selected.

Threat Assessment Strategies

This research sought to infer human information processing strategies from observed firing priorities in simulated anti-air warfare (AAW) engagements. The operator's task was to defend "ownship" by launching missiles against a raid of incoming targets that were equally lethal and approached at one of three speeds from various bearings. Figure 2 shows a snapshot of the simulation in progress.

The research issues were: (1) What is the operator's normal processing mode? (2) Does an explicit processing instruction yield evidence that the instructed strategy is indeed invoked? (3) Does increased workload produce an identifiable shift in strategy? (4) What are the implications for the design of decision aids?

Although interception of all targets at maximum range is the ideal goal, limits in human processing made it more appropriate to seek to *minimize ownship's vulnerability*,² or total exposure to threat. Thus, a vulnerability strategy was defined as "Always fire at

²Let the momentary vulnerability induced by a target be equal to $1/t$ where t is the time remaining until the target would penetrate and score a hit against ownship. The total vulnerability incurred in an entire AAW engagement is then taken as the sum of the momentary vulnerabilities, accumulated over all targets and all updates.

Procedurally, the increased likelihood of reenlisting was debited by the difficulty-of-implementing scale rating.

Eighteen incentives thought to be the most amenable to change by the Navy were used in this analysis for each segment. The optimal menu of five incentives that was identified varied by segment, but several incentives appeared frequently. The most popular incentives (adjusted for difficulty of implementing) across all eight segments were:

1. Guaranteed one of their top three choices of duty location.
2. Free dental coverage for dependents.
3. Permanent duty location for up to 5 years.
4. Indefinite reenlistment contract.

Each of these appeared at least six times across the eight segments and showed high net gain across the sample. In particular, the incentive to allow permanent duty location for up to five years provides an extremely good return even though its difficulty of implementation rating is quite high.

Summary

After various analyses probing numerous different reenlistment market segments, the most consistent finding is that the influential incentives are strong across all groups. The pattern of incentive effect on increasing or decreasing reenlistment intention is basically the same for identifiable groups. This effort included two unique analyses: (1) measurement of the maximal reach for sets of themes to promote reenlistment, and (2) identification of optimal reenlistment incentive menus. Market segmentation techniques are appropriate and efficient for application to retention issues.

ALTERNATIVE MILITARY MANPOWER SUPPLY METHODOLOGIES

Jules I. Borack

Background

Although military manpower specialists have used the phrases "supply of manpower for military service" or "military personnel supply" with increasing frequency, there is no commonly accepted definition of the term "military manpower supply." Rather, the term supply appears to symbolize the method used by an individual planner or researcher, rather than an underlying phenomenon. Because of the bewildering assortment of definitions and projections, a prospectus that combines various manpower supply methods into a logical framework is needed.

Objectives and Approach

The primary objectives of this effort were to analyze the principal methods used by military manpower supply specialists and to suggest a prospectus for combining them into a logical framework. Three distinct methods used by manpower supply researchers were analyzed: (1) econometric model development, (2) surveys of interest/intentions to join the military, and (3) demographic analyses.

Results

The definitions of supply inherent in the approaches addressed are quite dissimilar. Econometric models define supply as the expected value of "high-quality" contracts or accessions; surveys define supply as the number and composition of individuals who are planning (or are interested in) a military career; and demographic approaches define supply as the number and composition of individuals who are able to fulfill military entrance criteria.

Each method possess several strengths and weaknesses. Econometric models are easy to implement and define supply in a directly usable fashion. However, they are unable to incorporate variables that are not directly quantifiable and models cannot be easily developed for demand-constrained or nontraditional populations. Conversely, manpower supply surveys do not define supply in a directly implementable manner but are very useful in measuring the relative size of a supply pool. In addition, these surveys investigate the entire spectrum of the nation's youth--not just those youths who have chosen to join the military. Finally, demographic approaches are useful in providing a tool for assessing the impact of alterations in accession standards. Demographic techniques, however, do not by themselves aid in the assessment of key policies that would permit the military to balance supply and demand efficiently.

Conclusions and Recommendations

These findings indicate that no single method provides all the information necessary for a full understanding of the accessioning process. A "good" supply model should use the best demographic techniques to establish accurate bottom-line populations and combine them with interest/intent data obtained through surveys and relevant economic predictors. A logical framework that integrates these diverse approaches represents supply as a dynamic interplay rather than a specific model, survey, or analysis.

DEVELOPMENT OF COMPUTER-BASED WRITING AIDS¹

Frederick R. Chang

Background

Increasing national interest in the quality of written communication is evidenced by the number of state legislatures who have enacted requirements for plain English in public documents and contracts. Government writing ("governmentese"), in particular, has been the target of much action. Recently, for example, a federal judge in Brooklyn, New York, ordered the government to remove the gobbledygook from Medicare form letters. In a verdict on a class-action suit, the judge ruled that the language used in Medicare letters could not be understood by the recipients and, in fact, did not qualify as English (Simply Stated, 1984).

There is no shortage of guidelines for improving either government or Department of Defense writing, yet the problems persist. Either the guidelines are not being read and followed, the procedures are too difficult and time-consuming to implement, or the suggestions themselves are not adequate.

As word processors and computer systems are gaining widespread acceptance, it appears the potential now exists to develop computerized writing assistants. A variety of automated writing tools, such as spell checkers and text formatters, already exist, but the potential exists for more advanced tools. The few automated tools that are available tend to be lacking in two important respects: First, these writing tools should incorporate findings from the psycholinguistic literature. Much is known about how people comprehend sentences, paragraphs, and texts in general, and it is important to use this knowledge (Kieras, 1984). Second, it is important to provide the writer with an efficient interface to the computer (cf. Norman, 1981). Current programs have not provided clean, efficient user interfaces.

Objective

This effort concentrated on the user interface. The objective was to develop an efficient, easy-to-use, computer-based writing assistant that helps a writer follow the "plain English" guidelines specified in the recent edition of the Navy Correspondence Manual (Secretary of the Navy, 1983). The first chapter of this Navy instruction details fairly concrete steps to improve writing, consistent with plain English initiative. The ability to implement these guidelines easily is potentially of great importance to the effectiveness of Navy communication.

Approach

A set of design principles was determined to be crucial to an effective computer-based writing assistant: The system should be (1) easy to use, (2) provide specific information about what is wrong with the document, (3) provide specific recommendations about how to improve the document, and (4) have a quick and inexpensive user interface. With these guidelines in mind, the REVISE system was developed.

¹This work has transitioned to task PE63720N, Z1772: Authoring Instructional Materials. Results of this FY84 work will be applied to the revision of the NATO Sea Sparrow missile system technical manual in a project sponsored by the NAVSEA NATO Sea Sparrow Project Office (C06P).

Data Base

The Navy instruction includes a discussion of the importance of using simpler words and phrases and, in general, the importance of economy in writing. The instruction also includes a "hit list" of excessively wordy or commonly misused phrases along with suggestions for improving them. This listing was the foundation of the data base in REVISE. The items were modified and enhanced for use in the system.

Operation

After the writer has prepared a draft document, he or she can then run the document through REVISE. The program runs interactively and analyzes each sentence separately. If the system detects a word or phrase contained in the data base of wordy or unclear expressions, it displays the entire sentence and highlights the awkward part. It then displays alternative words or phrases that could replace the flagged items. The system also displays a menu of options as a quick, easy way to make changes to the document. Once the revision is complete, the system creates a file (on disk) that contains all changes. The original file is left intact.

Results

A collection of Navy documents was run through the system, and changes suggested by REVISE were made. In general, over 90 percent of the awkward words and phrases flagged by the system were appropriate targets for revision according to the sentence context. The original and revised documents were compared on a variety of text characteristics. The revised documents showed significant improvements on a variety of measures thought to influence comprehensibility. For example, the revised documents generally had more common (higher frequency) words, fewer passive constructions, fewer nominalizations, improved readability scores, and the like. There were no significant changes in sentence construction measurements.

Conclusions

Although a full-scale comprehensibility evaluation was beyond the scope of this research, REVISE did make measurable changes in a collection of Navy documents in ways that are known to improve comprehensibility. The system described here represents an example of a computerized writing assistant that can help military personnel to write plain English. Although REVISE improved Navy documents in some important ways, the improvements were limited in other ways. A variety of other computer-based writing tools that are now under development will hopefully provide increased capability.

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APPENDIX A
INDEPENDENT RESEARCH/INDEPENDENT EXPLORATORY DEVELOPMENT
PUBLICATIONS AND PRESENTATIONS

INDEPENDENT RESEARCH PUBLICATIONS

- Greitzer, F. L., & Hershman, R. L. (1984). Modeling decision making strategies in simulated AAW operations. Proceedings of the Seventh MIT/ONR Workshop on C³ Systems, LIDS-R-1437, 145-150.
- Greitzer, F. L., & Hershman, R. L. (July 1984). Inferring threat assessment strategies in simulated antiair warfare (AAW) operations (NPRDC Tech. Rep. 84-47). San Diego: Navy Personnel Research and Development Center.
- Montague, W. E., Barr, W. W., & McKnight, T. D. (November 1984). TESTER: A program for constructing on-line interactive graphic tests for understanding simple circuits. (NPRDC TL 85-1). San Diego: Navy Personnel Research and Development Center.
- Montague, W. E. (August 1984). Aiding classroom instructors to enhance student achievement (NPRDC Training Laboratory, preliminary report submitted for TTCP UTP-2.)
- Montague, W. E. (In preparation). Diagnosing Navy trainees' problems in understanding basic electricity (NPRDC Tech. Rep.). San Diego: Navy Personnel Research and Development Center.
- Montague, W. E. (In preparation). An evaluation of a revision of course materials for basic electricity using qualitative diagnostic tests (NPRDC Tech. Rep.). San Diego: Navy Personnel Research and Development Center.
- Saxon, C. R., & Hershman, R. L. (1984). Human information processing in a signal detection task. Proceedings of the Seventh MIT/ONR Workshop on C³ Systems, LIDS-R-1437, 139-144.

INDEPENDENT RESEARCH PRESENTATIONS

- Baker, M. S. (April 1984). Generalizable cognitive strategies. Paper presented at the Ninth Psychology in the Department of Defense Symposium, Colorado Springs, Colorado.
- McDonald, B. A. (April 1984). Cognitive and emotional processing: Implications for learning strategies. Paper presented at the Ninth Psychology in the Department of Defense Symposium, Colorado Springs, Colorado.
- Montague, W. E. (September 1984). Diagnosing causes of errors on simple circuit problems with a qualitative test. Paper presented at a conference on an inventory of research results concerning the representation of student's knowledge in electricity and its uses for instruction. Ludwigburg, West Germany.

INDEPENDENT EXPLORATORY DEVELOPMENT PUBLICATIONS

Liang, T. T. (July 1984). Network formulation of multiple-criterion problems for developing an integrated personnel distribution system in the Navy (NPRDC Tech. Rep. 84-49). San Diego: Navy Personnel Research and Development Center.

Borack, J. I. (May 1984). A framework for integrating alternative military manpower supply methods (NPRDC Tech. Rep. 84-42). San Diego: Navy Personnel Research and Development Center.

INDEPENDENT EXPLORATORY DEVELOPMENT PRESENTATIONS

Liang, T. T., & Shao-ju, L. (May 1984). An integrated personnel distribution system in the Navy. Paper presented at the Joint National Meeting of the Institute of Management Sciences/Operations Research Society of America, San Francisco.

Borack, J. I. (June 1984). A framework for integrating alternative military manpower supply. Paper presented at the International Institute of Management Sciences, Copenhagen, Denmark.

APPENDIX B
PROJECTS THAT HAVE TRANSITIONED

INDEPENDENT RESEARCH PROJECTS

1. The FY83 and FY84 results of the work under this project title (ZR000-01-042-04.014) will provide the basis for evaluating the effects of changing the delivery of the Navy Basic Electricity and Electronic Course from self-paced to group-paced/lecture based instruction. The CHANGE diagnostic test developed for this project is being used for an ONR supported research effort to test the usefulness of adaptive testing models for instruction.
2. Work performed under the title "Generalizable Cognitive Strategies" (ZR000-01-042-06.017) was completed in FY84 and transitioned to Exploratory Development task PE62763N, RF63622801; "Generic Problem Solving."
3. Some of the work undertaken in FY84 under the project title "Cognitive Factors in Learning and Retention" (ZR000-01-042-06.027) will be used for Advanced Development tasks PE63720N; Z1772-002: Functional Context Training, and PE62763N; RF63522801: Classroom Instructional Process.
4. "Acquiring Skill from Work Experience" (ZR000-01-042-08.023) have led to the proposal of new FY87 6.2 level research in officer career development. That research would look at both the optimum length of operational (sea), quasi- operational (sea-related shore), and nonoperational (unrelated shore) tours and the sequences of tour assignments required to produce effective operational and nonoperational commanding officers. Support for such a proposal has been received from OP-13.
5. Results from the project titled "Models of Human Performance with Application to Decision Aiding" (ZR000-01-042-09.022) have been incorporated into Exploratory Development Task PE62757N; SF57525601: "Decision Aiding in Combat Systems."

INDEPENDENT EXPLORATORY DEVELOPMENT PROJECTS

1. The results of work under the project title "Multiple Criterion Optimization Techniques" (ZF66-511.013) have influenced work in three FY85-funded efforts: (a) PE63707N, Z1770: Personnel Assignment System, (b) PE62763N, RF63-521-004-031: Career Management Planning, and (c) PE99000N, C0073-002.02: CLASP System Development.
2. Work under the project title "Self-Defense Tactical Trainer" (ZF66-512-001.008) has been transitioned to Advanced Development task PE63720N, Z1772: Tactical Decision Training.
3. ZF66-512-014: Development of Computer-based Writing Aids. This work has transitioned to task PE63720N, Z1772: Authoring Instructional Materials. Results of the FY84 work will be applied to the revision of the NATO Sea Sparrow missile system technical manual in a project sponsored by the NAVSEA NATO Sea Sparrow Project Office (C06P).

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